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Estimation of K, U and Th in Precambrian ores by low-level γ-ray spectroscopy

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Abstract : Gamma-ray spectroscopy technique has been employed to estimate the concentration of three large ion lithophile elements, namely K, U and Th present in banded iron-formations, ferromanganese oxides and chromites collected from different mines of eastern Indian geological belt The results obtained by this method have been discussed on the basis of ancient ocean condition, effect of weathering and on selectivity of large ion lithophile elements towards major elemental phase, *i e* , silica, iron, chromium and manganese.

Keywords : Precambrian ores, γ-ray spectroscopy, nuclear geophysics, large ion lithophile elements, Th/U ratio

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During the last few decades, natural radioactive nuclides and their decay products are widely used in various branches of sciences including biological [1], environmental [2,3], cosmological [4,5] and several geological purposes [6–12]. In earth sciences, its sole use mostly dominated by giving emphasis to geochronology as traces in various geochemical and petrochemical processes [10]. Furthermore, the assessment of the amount of radioactive elements, the major internal heat source of the earth, has been subjected to several studies due to their importance in modeling the thermal evolution of the lithosphere, and in rocks for basic understanding of the thermal history of the earth. These are relatively abundant, their heat production is significant, and their half-lives are comparable to the age of the earth. The natural radioactive isotopes, such as ^{238}U, ^{235}U, ^{232}Th, and ^{40}K contribute to the most terrestrial heat flux significantly and still are the main component in warming the interior of the earth. The rate of heat production by the two uranium isotopes 0.72 cal g^{-1}/year (U^{238}) and 4.7 cal g^{-1}/year (U^{235}) respectively, whereas Th^{232} contributes 0.21cal g^{-1}/year, and the principal heat-producing isotope K^{40} donates 0.21 cal g^{-1}/year [12]. The study of the radioactive elements is also relevant in other fields of geosciences. In magmatic systems, the high compatibility of U and Th (large ion lithophile elements) is of great importance in understanding their evolution, *i.e.* bimodality, fluxed or metasomatised mantle magmas and very selective partial melting of evolved continental crust for origin of rhyolites, *etc.* [7]. These elements are fundamental for understanding the nature of the mantle and crust, and their heat generating potentials. An attempt has been made by the authors to estimate the amount of natural radioactivity present in these selected geological materials, followed by quantification of K, U and Th has been carried out. The present method is simple, non-destructive with mostly no sample pretreatment requirement, and very much important for routine analysis for the above purposes. In the present investigation, emphasis has been given on two basic aspects considering representative samples. One aspect of the study is to evaluate the variation in Th/U

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ratio with weathering by taking selected samples, where variation in weathering is considered by earlier reported Mössbauer spectroscopy or textural study. The other aspect is to investigate the affinity of U and/or Th towards any of the major elemental phase, namely silica, iron, chromium and manganese, if present there.

Various geological materials have been collected from several mines of eastern Indian belt, and their geological locations are incorporated in Table 2. The banded iron-formations [13,14] and ferromanganese oxide ores [15] are of Archean origin, whereas the chromites are of Proterozoic origin. In case of banded iron-formations, the iron and silica phases were separated before making powders for gamma-ray measurements. The Mössbauer study reveals that the three banded iron-formations samples are of progressive degree of weathering from *Keonjhar* to *Tomka* through *Gorumahisani* [13]. The representative chromite samples were selected from *Sukinda* chromite geological belt. The *Kathpal* sample has been found to be undergone minimal weathering whereas the *Kaliapani* sample is maximum affected by weathering condition, evident from visual and ore microscopic study. For radioactivity measurement, the dry powdered samples were stored in airtight (sealed with cello-tapes) cylindrical plastic containers (6.5 cm diameter and 7.5 cm height) at least for 45 days so as to ensure that ^{226}Ra and ^{228}Th attain radioactive equilibrium with their respective daughters. A 20% efficiency high purity germanium (HPGe) detector with a resolution of 1.95 keV at 1.33 MeV and having a volume of 77 cm^3 was used for gamma ray measurements. Emitted gamma rays from the samples were collected by the HPGe detector with lead shielding (thickness of two inches) and were recorded using a PC based multi-channel analyser [16]. The total energy window has been set from 0.10 to 2.8 MeV. The γ-ray spectrometer was calibrated with uranium and thorium ores procured from Bhabha Atomic Research Center, Mumbai. On the basis of replicate analyses, the precision of the gamma-ray spectrometry determinations is found to be within 5–7%. The obtained gamma ray spectra were analysed by using ULTIMA-4 (supplied by DRA Technologies, USA) and various radioactive nuclides including ^{214}Bi, ^{208}Tl and ^{40}K were quantified. The detected concentration levels from the background spectrum are provided in Table 1.

Table 1. Minimum detectable concentration levels from the background spectrum

Name of the LILE (primordial nuclide)	Minimum detectable concentration from the background spectrum (Bq kg^{-1})
Uranium (^{238}U)	4.8
Thorium (^{232}Th)	1 9
Potassium (^{40}K)	1 5

The gamma-ray spectrum of banded iron-formation sample is presented in Figure 1. The determination of activity levels of U and Th are based on measured

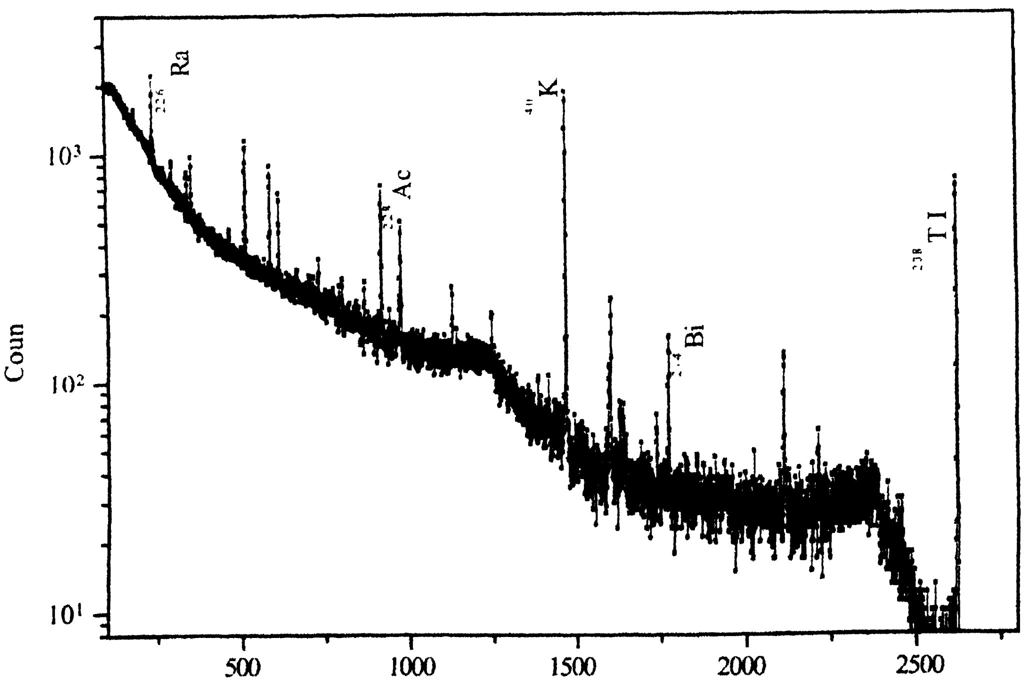

Figure 1. Gamma-ray spectrum of banded iron formation.

γ-radiation from the decay of 1.76 MeV in the ^{238}U decay series and from 2.62 MeV in the ^{232}Th series, whereas the estimation of concentration of K is based on the decay of ^{40}K (1.46 MeV). The activity levels of radionuclides are obtained as Bq kg^{-1}, which were subsequently converted to concentrations according to the conversion factors provided in Ref. [5], as these can be applied to primordial nuclides for which the measurement of concentrations by weight can be converted. The conversion factor is 81 ppb, 246 ppb and 32.3 ppm (concentrations by weight) for each 1Bq kg^{-1} activity for ^{238}U, ^{232}Th and ^{40}K, respectively. The measured concentrations of the three large ion lithophile elements are provided in Table 2. It is evident from the data that the Th/U ratio of banded iron-formations (Archean time) and chromites (Proterozoic) are similar irrespective of large geological time gap. Also, there is no detectable variation in weathering while considering the progressive weathered samples of banded iron-formations and chromites. Considering samples from Tomka (Table 2), it can be inferred that silica and iron do not show any significant variation towards Th/U ratio. But, the most interesting phenomena observed while considering ferromanganese oxide ore, which bears significantly low uranium concentration and Th/U ratio indicate probable affinity of the later towards manganese phase, although the cause and mechanism is unknown. As this preliminary investigation is interesting, further extensive work is under progress and will be reported in future. See also Refs [17,18]

As a summary, the low-level γ-ray measurement has been presented in this paper on Archean banded iron-formations, ferromanganese oxide ores and also on Proterozoic chromites using an HPGe detector. The Th/U ratios have been found out. It is observed that in Archean situation, there is no particular affinity either of U or Th towards selective elemental phase, *i.e.*, silica or iron. The Archean banded iron-formations and Proterozoic chromites bear nearly similar Th/U ratio irrespective of wide difference in their origin. On contrary to these, ferromanganese oxide ores bears significantly lower Th/U ratio indicating probable affinity of uranium towards manganese. Furthermore, it was observed that the chemical weathering has no significant effect on the Th/U ratio during Precambrian situation.

Table 2. Potassium, uranium and thorium concentrations, and Th/U ratio in banded iron-formations, chromites and ferromanganese oxide ores

Local name of the deposit	Sample type	Location		K (ppm)	Th (ppb)	U (ppb)	Th/U
		Longitude	Latitude				
Gorumahisani	Banded iron-formation (Iron phase)	85° 53' 00"	22° 01' 00"	4741	21089	1031	20 45
Tomka	Banded iron-formation (Iron phase)	85° 49' 00"	21° 12' 00"	4774	18781	911	20 62
Tomka	Banded iron-formation (Silica phase)	85° 49' 00"	21° 12' 00"	4794	20148	830	24 27
Keonjhar	Banded iron-formation (Iron phase)	85° 29' 00"	22° 01' 00"	6019	20769	1070	19 41
Kathpal	Chromite (Minimum-weathered)	85° 48' 00"	21° 03' 12"	5091	22214	1037	21 42
Kaliapani	Chromite (Highly-weathered)	85° 43' 00"	21° 01' 00"	4867	20832	940	22 16
Silzora	Ferromanganese oxide ore	85° 22' 40"	21° 53' 40"	6307	21121	1631	12 95
Dubuna	Ferromanganese oxide ore	85° 24' 30"	21° 51' 30"	5480	21092	1631	12.93
Kalimati	Ferromanganese oxide ore	85° 24' 40"	21° 52' 00"	4397	21602	1795	12 03
Gurda	Ferromanganese oxide ore	85° 23' 00"	21° 55' 20"	6015	20732	1675	12 38

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References

[1] C Papastefanou *J Environ. Radioactivity* **53** 67 (2000)

[2] J M Smoak, W S Moore, R C Thunnel and T J Show *Marine Chemistry* **65** 177 (1999)

[3] A Martinez-Aguirre, M Garcial-Leon and M Ivanovich *Nucl. Instrum Meth* **A339** 287 (1994)

[4] G Heusser *Nucl Instrum Meth.* **B58** 79 (1991)

[5] G Heusser *Annu Rev Nucl Part Sci* **45** 543 (1995)

[6] T C Atkinson, R S Harmon, P L Smart and A C Waltham *Nature* **272** 24 (1978)

[7] P Chiozzi, V Pasquale and M Verdoya *Appl. Geophys* **38** 209 (1998)

[8] T Yokoyama, A Makishima and E Nakamura *Chem Geol.* **181** 1 (2001)

[9] D K Talbot, J D Appleton, T K Ball and M H Strutt *J Geochem Exploration* **65** 79 (1998)

[10] P Chiozzi, V Pasquale, M Verdoya and P De Felice *Appl. Radiat. Isot* **53** 215 (2000)

[11] P Chiozzi, P De Felice, V Pasquale, D Russo and M Verdoya *Appl. Radiat. Isot.* **51** 247 (1999)

[12] K B Krauskopf *Introduction to Geochemistry* (New York McGraw Hill) p 610 (1967)

[13] P K Nayak, D Das, V Vijayan, P Singh and V Chakravortty *Nucl. Instrum Meth.* **B184** 649 (2001)

[14] P K Nayak, D Das, V Vijayan, P Singh and V Chakravortty (*Nucl Instrum. Meth. B*) (in press)

[15] P K Nayak, V Chakravortty, V Vijayan and P Singh (*Int J PIXE*) (Under Publication)

[16] V Vijayan *J. Environ Pollution* 7 35 (2000)

[17] P K Nayak, D Das, S N Chintalapudi, P Singh, S Acharya, V Vijayan and V Chakravortty *J Radioanal. Nucl. Chem* **254** 351 (2002)

[18] M Ashok, T R Rautray, P K Nayak, V Vijayan, V Jayanthi and S N Kalkura *J. Radioanal Nucl. Chem.* **257** 333 (2003)